ASSESSING MECHANISMS OF INJURY AS PREDICTORS OF SEVERE INJURY FOR ADULT CAR AND TRUCK OCCUPANTS

Ruben Buendia[1,2,3]
Stefan Candefjord[1,2,3]
Bengt-Arne Sjöqvist[1,2,3]
[1]SAFER Vehicle and Traffic Safety Centre at Chalmers
[2]Department of Signals and Systems, Chalmers University of Technology, 412 96, Gothenburg, Sweden
[3]MedTech West, Sahlgrenska University Hospital, Röda Stråket 10 B, 413 45 Gothenburg, Sweden

Paper Number 15-0427

ABSTRACT

This study evaluates Mechanisms of Injury (MOI) that can be rapidly assessed at the scene of accident and may be used as predictors of severe injury for traffic accidents involving occupants in cars or trucks. The objective is to increase the knowledge of how MOI can be used to differentiate whether a patient is severely injured or not. This knowledge can be used to improve trauma triage systems. Furthermore, an objective is to analyze safety differences between cars and light/heavy trucks. The scope is adult occupants of cars, light and heavy trucks injured in accidents registered in the Swedish Traffic Accident Data Acquisition (STRADA) database from 2003 to 2013. Partition between severe and non-severe injury was done according to the Injury Severity Score (ISS) with ISS > 15 as definition of severe injury. The MOIs considered were: belt use, airbag deployment, posted speed limit, elderly occupant (age ≥ 55 years), sex, type of accident (single, intersection, turning, head-on, overtaking, rear end, tram/train, wild animal or other) and location of the accident (urban or rural). The different MOI were evaluated individually using univariate chi-square tests and together using multivariate logistic regression models. Results show that belt use is the most crucial factor determining risk of severe injury for all vehicle types. Age is the second most important factor, with elderly occupants exhibiting a higher risk. Head-on accidents are the most dangerous for cars and light trucks while single accidents are the most dangerous for heavy trucks. Belt use compliance is much lower for truck occupants. This appears to be the main reason for the frequency of severe injury being higher for truck occupants than for car occupants.

INTRODUCTION

Rapid transport of severely injured trauma patients to a trauma center substantially decreases mortality [1, 2]. Medical examination of the patient with support from a triage protocol and observations of characteristics of the accident are the main tools emergency personnel have for recognizing patients with severe injury. Schoell et al. [3] stated that improvement of triage systems is nowadays the most important area to address to continue reducing fatal and severe injuries for motor vehicle accidents. Therefore, maintaining, updating and improving trauma triage systems is of utmost importance.

Triage systems are in general primarily based on physiological and anatomical criteria and secondly on Mechanisms of Injury (MOI). The value of MOI is to detect occult injuries and reduce undertriage. A study with around one million trauma patients concluded that using physiologic and anatomic criteria alone lead to undertriage [4]. This strongly supports the use of MOI in triage systems.

In Sweden RETTS [5] is the most widespread triage system. The MOI that apply for motor vehicle crashes are: occupant ejected from vehicle, vehicle rollover, person entrapped, and deployment of airbag. For car accidents there is an additional criteria: estimated speed > 60 km/h. We believe that risk for severe injury can be predicted with higher precision, i.e. with reduced overtriage and/or undertriage, by adding complementary MOI to the triaging process.

In order to improve triage systems for traffic accidents this study evaluates the predictive power of severe injury for MOI that can rapidly be assessed at the scene of accident. In addition a comparison between cars, light and heavy trucks of how these MOI relate to injury severity was performed.

The scope of the study is adult occupants in cars, light and heavy trucks for accidents registered in the Swedish Traffic Accident Data Acquisition (STRADA) database for eleven years, from 2003 to 2013. The evaluation of the predictors is performed by comparing the proportion of patients with severe injury for each level of the variable, univariate analyses of association with probability of severe injury using chi-squared tests and multivariate analyses using logistic regression models. The logistic regression models were developed in the studies by Buendia, Candefjord et al. [6, 7].

METHODS

STRADA is the Swedish Transport Administrations national information system for traffic accidents occurring on the public roads of Sweden. It included two sources of data, independent reports from the police and the hospital treating the patient. The database is contained in a Microsoft Access® database file. An introduction to STRADA is available in [8].

Between calendar years 2003 to 2013 near 650 000 injured persons can be found in STRADA. Each accident has a unique ID which is shared between the police report and the hospital report and is the link between accident and patients. We included only accidents involving injured occupants traveling in a car or a truck where both a police and a hospital report were available. In the case of cars, subjects with missing information in any predictor considered were not included.

The observations were divided into cars, light trucks, i.e. trucks with total weight up to 3500 kg, and heavy trucks, i.e. trucks with a total weight over 16 500 kg, according to the Swedish official classification of trucks. Trucks of medium weight were not considered because they were not sufficient in numbers to feed a model with enough statistical power.

The total number of accident victims was 29 128 for cars, 2 775 for light trucks and 922 for heavy trucks. They were injured in 22 607, 2 608 and 903 accidents for cars, light trucks and heavy trucks, respectively.

Casualties were classified as severely injured or not according to the Injury Severity Score (ISS) with ISS > 15 used as definition of severe injury, i.e. a victim with ISS > 15 is classified as severely injured and a victim with ISS < 15 is classified as non-severely injured. This was the dependent variable for all analyses. The proportion of severely injured was 2.0 % for cars, 2.9 % for light trucks and 4.0 % for heavy trucks. The MOI used as predictors are detailed in Table I.

The software used for the statistical analysis was IBM SPSS Version 22. Chi-squared tests were used to assess the univariate association with probability of severe injury for each predictor, where the null hypothesis was no association. $p < 0.05$ was considered statistically significant, casting doubts over the null hypothesis. The multivariate analyses were performed using logistic regression modelling. p-values and odds ratio (OR) for each predictor were derived. Logistic regression is a maximum-likelihood method commonly used in studies of traffic accidents, see e.g. [9, 10].

Table 1: MOI description. For each MOI level the percentage of casualties having that characteristic is given.

Predictor	Levels	Frequency			Description
		Cars (%)	Light Trucks (%)	Heavy Trucks (%)	
Belt Use	Unknown		12	17	Whether the casualty was using the seat belt at the moment of the accident
	Unbelted	94	8.7	28	
	Belted	5.9	79	55	
Airbag Deployment	Unknown		33	50	Whether the airbag was deployed at the moment of the accident in case there was an airbag in the seat of the casualty
	Undeployed	60	38	45	
	Deployed	38	26	1.6	
	No Airbag	2.1	2	2.9	
Accident Type	Turning	23*	4.4	1.7	Classification according to the following types of accident: Intersection, collision of vehicle in an intersection; Turning, collision with a vehicle on a turning maneuver; Head-on, frontal collision of vehicles; Overtaking, collision with a vehicle on a overtaking maneuver; Single, vehicle collides with stationary object or departs from the road; Rear End, one vehicle collide with another from behind, Tram/Train, a vehicle collide with a tram or a train, WLA, a vehicle collide with a WLA, Other, other kind of accident.
	Intersection	23*	13	2.8	
	Head-on	13*	11	13	
	Overtaking	13*	2.2	1.3	
	Single	31	34	61	
	Tram/Train	0.2	0.5	1.2	
	Rear End	27	28	14	
	WLA	3.2	2.8	0.8	
	Other	3.1	4.2	3.8	
PSL	Unknown		11	12	Posted Speed Limit in the segment of road where the accident took place
	30	1.2	1.1	0.5	
	40	0.8	0.7	0.3	
	50	29	18	12	
	60	1	1.2	0.3	
	70	31	30	26	
	80	4.3	4.4	5.5	
	90	20	18	29	
	100	2.9	3.9	2.7	
	110	8.8	9.7	12	
	120	0.7	0.9	1.2	
Accident Place	Unknown		8.8	8	Whether the accident took place in an urban or rural environment, i.e. in or out a population center. Circumvallation roads are considered urban.
	Urban	38	27	15	
	Rural	62	64	76	
Elderly	Under 55	78.4	84	83	The age 55 years old was used because the National Expert Panel's decision to retain age 55 as a criterion for consideration in the Field Triage Decision Scheme (Sasser et al., 2012).
	Over 55	21.6	16	17	
Sex	Male	54	82	92	Whether the victim was male or female
	Female	46	18	7.6	

***For car accidents Overtaking was merged with Head-on and Turning was merged with Intersection.**

RESULTS

Belt use and its relation to frequency of severe injury are shown in Figures 1 and 2 respectively. Results of the univariate analyses are shown in Table 2 which includes degrees of freedom, *p*-value for each predictor and the percentage of severely injured patients associated with each predictor level. Table 3 shows the results for the multivariate logistic regression models. For each predictor the statistical significance (*p*-values), β-coefficients for the regression equation and OR are shown.

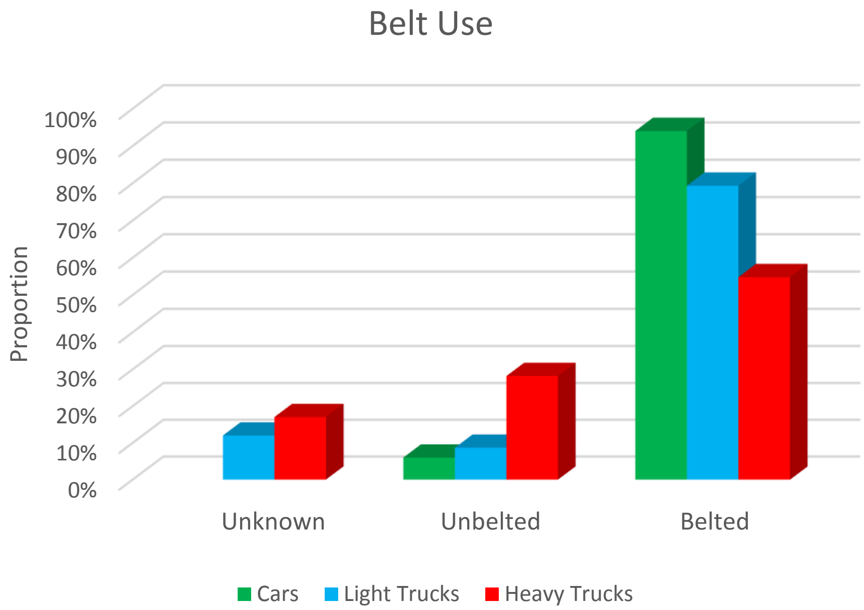

Figure 1: Belt use compliance for the different occupant groups. Note that subjects classified as unknown were removed in cars.

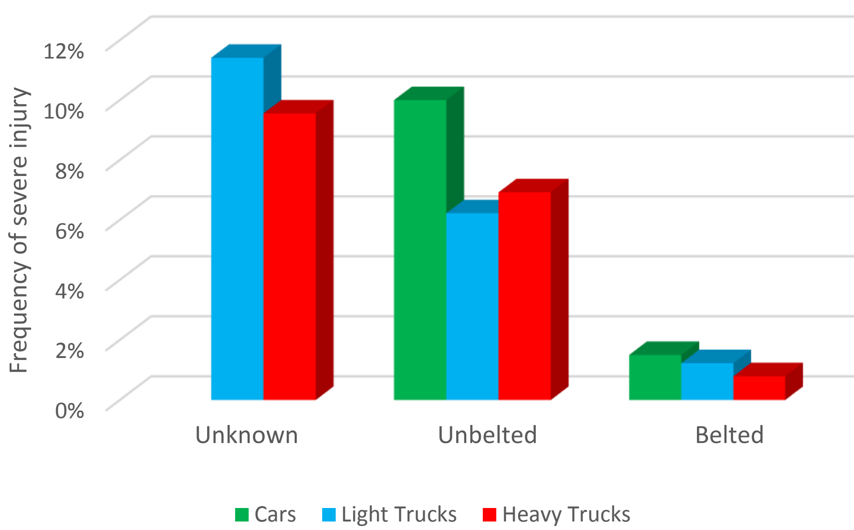

Figure 2: Frequency of severe injury versus belt use. Note that subjects classified as unknown were removed in cars.

Table 2: Univariate analysis of MOI using chi-square tests of association. *p*-values and percentage of severely injured patients associated with each of its levels are shown.

Variable	*p*			Variable Levels	Percent of subjects suffering severe injury for each variable level		
	Cars	Light Trucks	Heavy Trucks		Cars (%)	Light Trucks (%)	Heavy Trucks (%)
Belt Use	< 10e-4	< 10e-4	< 10e-4	Unknown Unbelted Belted	 10 1.5	11 6.2 1.2	9.6 6.9 0.8
Airbag Deployment	0.0030	< 10e-4	0.18	Unknown Non-deployed Deployed No Airbag	 1.8 2.3 2.6	5.4 1.1 2.2 3.6	5.4 2.6 0.0 3.7
Accident Type	< 10e-4	< 10e-4	0.17	Turning Intersection Head-on Overtaking Single Tram/Train Rear End WLA Other	1.2* 1.2* 6.1* 6.1* 2.4 2 0.3 2 1.9	0.8 1.7 9.2 0 3 27 0.9 1.3 4.3	0 0 0.8 0 5.5 9.1 3 0 0
PSL	< 10e-4	0.24	0.62	Unknown 30 Km/h 40 Km/h 50 Km/h 60 Km/h 70 Km/h 80 Km/h 90 Km/h 100 Km/h 110 Km/h 120 Km/h	 0.6 0.8 0.9 1.0 2.1 2.5 4.1 1.1 0.9 1.1	3.5 0 0 1.6 0 3.1 1.7 4.4 0.9 3.3 4	3.7 0 0 7.4 0 5.1 2.0 2.6 0.0 3.7 9.1
Accident Place	< 10e-4	0.23	0.17	Unknown Urban Rural	 1 2.6	3.3 2 3.2	0 4.9 4.3
Elderly	< 10e-4	0.0001	0.45	Under 55 Over 55	1.6 3.6	2.4 5.7	3.8 5.1
Sex	< 10e-4	0.18	0.60	Male Female	1.4 2.5	3.1 2	4.1 2.9

***For car accidents Overtaking was merged with Head-on and Turning was merged with Intersection.**

Table 3: Multivariate analysis of MOI using logistic regression models. *p*-values, β coefficients and odds ratio are shown.

Predictors	β			*p*			e^{β}		
	Cars	**Light Trucks**	**Heavy Trucks**	**Cars**	**Light Trucks**	**Heavy Trucks**	**Cars**	**Light Trucks**	**Heavy Trucks**
Belt (Unbelted)				< 10e-4	< 10e-4	< 10e-4			
Belted	-2.1	-2	-2.4				0.18	0.14	0.090
Unknown		0.22	0.33					1.2	1.4
Airbag (Non-deployed)				0.33	0.20	0.28			
Deployed	0.10	0.31	-16				1.4	1.4	< 10e-4
No Airbag	0.34	1.4	2.1				1.6	4.0	8.2
Unknown		0.64	0.60					1.9	1.8
Over55/Under55	0.92	0.78	0.48	< 10e-4	0.0050	0.29	2.7	2.2	1.6
Female/Male	0.33	-0.32	-0.18	< 10e-4	0.39	0.82	1.4	0.73	0.84
Place (Urban)				< 10e-4	0.28	0.60			
Rural	0.48	0.48	0.51				1.6	1.6	1.7
Unknown		0.53	-18					1.7	< 10e-4
ATC (Head-on)				< 10e-4	< 10e-4	.85			
Intersection	-1.5*	-1.5	-16				0.23*	0.22	< 10e-4
Other	-1.2	-1.1	-17				0.29	0.33	< 10e-4
Overtaking	**Ref***	-19	-16				**Ref** *	< 10e-4	< 10e-4
Rear end	-2.7	-2.4	1.5				0.07	0.09	4.7
Single	-1.1	-1.4	2.0				0.34	0.24	7.3
TramTrain	-0.43	0.90	2.0				0.65	2.5	6.5
Turning	-1.5*	-2.5	-16				0.23*	0.080	< 10e-4
Wild	-1.4	-2.6	-17				0.25	0.072	< 10e-4
PSL (Unknown)				< 10e-4	0.25	0.85			
30 Km/h	**Ref**†	-17	-19				**Ref**†	< 10e-4	< 10e-4
40 Km/h	1.1	-16	-18				2.9	< 10e-4	< 10e-4
50 Km/h	0.6	-0.85	1.1				1.8	0.43	2.9
60 Km/h	0.87	-18	-17				2.4	< 10e-4	< 10e-4
70 Km/h	1.0	-0.14	.50				2.7	0.87	1.7
80 Km/h	1.2	-0.72	.040				3.5	0.49	1.0
90 Km/h	1.5	0.51	-0.27				4.4	1.7	0.76
100 Km/h	0.85	-0.18	-18				2.3	0.83	< 10e-4
110 Km/h	0.40	0.55	-0.14				1.5	1.7	0.87
120 Km/h	0.86	0.84	0.26				2.4	2.3	1.3

***For car accidents Overtaking was merged with Head-on and Turning was merged with Intersection.**

†30 Km/h was the reference for cars unlike for trucks where the reference was "Unknown".

DISCUSSION

Proportion of severely injured subjects versus belt use

The proportion of severely injured subjects was higher for trucks than for cars, and higher for heavy trucks than for light trucks. The frequencies were 4.0 % for heavy trucks, 2.9 % for light trucks and 2.0 % for cars. These results were surprising because larger vehicles, especially heavy trucks, were expected to be safer due to heavier weight and the occupant compartment being placed higher above the wheelbase. Large differences in compliance of belt use were found to be the cause of these surprising results. These differences can be observed in Figures 1 and 2. Figure 1 shows that the percentage of belted subjects is much higher in cars than in trucks, and the compliance is particularly low at 55 % for heavy truck occupants. Figure 2 indicates that for belted and unbelted occupants, cars are less safe than both types of trucks.

In both types of trucks a significant percentage of cases had belt use registered as unknown, which is probably a consequence of that it was reported by the patient himself/herself. Figure 3 shows that cases where belt use was unknown have even higher frequency of severe injury than unbelted cases, a surprising finding for which we currently have no explanation. However, it is likely that most of these cases were unbelted. For cars, cases where belt use was reported as unknown were not included in the analyzed data since a high discrimination power was achieved when eliminating cases with missing information.

Belt use was by far the most significant predictor for all vehicle types. Moreover it was the only variable that was statistically significant for heavy trucks ($p < 0.05$). It should be noted that the statistical significance of the predictors is highly influenced by the size of the datasets, e.g. more predictors were statistically significant for cars. Nevertheless a comparison of the predictors between different vehicle types can be made according to their ranking within a vehicle type.

Association of the different predictors with probability of severe injury

It is difficult to draw conclusions regarding airbag as being a valuable predictor of severe injury. One reason is that the level was unknown for many truck accidents, another is that airbag deployment is likely to be biased towards more severe crashes. Moreover for heavy trucks only 15 cases had deployed airbag, with no severely injured occupants. However, it can be concluded that the association of airbag deployment with probability of severe injury is much smaller than for belt use. We recommend that use of airbag deployment and not belt use as criteria in RETTS should be reconsidered and further evaluated in field studies.

Regarding type of accident note that for cars overtaking accidents were merged with head-on and turning accidents were merged with intersection [6]. The effect of merging these types of accidents is weak because the number of accidents classified as overtaking and turning were relatively small. For cars and light trucks head-on accidents are the most dangerous ones, whereas rear-end accidents are the most common but the least dangerous. The results are very different for heavy trucks where single accidents are by far the most common as well as the most dangerous. It is surprising that for heavy trucks rear-end accidents showed a higher probability of severe injury than head-on accidents. These results show that different types of accidents have similar consequences for cars and light trucks but are very different for heavy trucks.

In all types of vehicles the majority of accidents included in this study occurred in roads with PSL 50, 70, 90 and 110 km/h, with over half of the accidents taking place on roads with PSL 70 and 90 km/h. Roads with PSL 90 km/h are most dangerous for cars and light trucks, whereas roads with PSL 50 km/h have the highest risk of severe injury for heavy trucks, which was unexpected. This result should be interpreted with caution since it is based only on 100 subjects.

Rural environments produced a substantially higher proportion of severely injured than urban environments for all types of vehicles. Despite that heavy trucks showed a higher proportion of severely injured in urban environments, after adjusting for all other predictors, i.e. in the multivariate logistic regression model (Table 3), the OR showed that rural environments are a risk factor with positive association. This may partially be due to that PSL 50 km/h, which was the PSL with highest associated risk of severe injury for heavy trucks, was correlated with urban environment.

Occupants over 55 years old has a substantially higher probability of being severely injured than younger occupants in all three types of vehicle. However this factor is more prominent for cars than for light and heavy trucks. Regarding sex, women have a higher risk of sustaining severe injury for cars but a lower risk for trucks. In principle women are more vulnerable to trauma than men [10], however for trucks this result points in the opposite direction.

CONCLUSIONS

Belt use is the most important factor influencing the risk of sustaining severe injury for occupants in cars and trucks involved in traffic accidents. We recommend including belt use as criteria for triage protocols. There is a need for information campaigns and other means for increasing belt use compliance for cars and trucks, in particular for heavy trucks.

The finding that single accidents account for over 60 % of all heavy truck accidents that produce injuries, and that this is the most dangerous type, point to a need for innovations to reduce them.

REFERENCES

[1] Haas, B., Gomez, D., Zagorski, B., Stukel, T.A., Rubenfeld, G.D. and Nathens, A.B., 2010. “Survival of the Fittest: The Hidden Cost of Undertriage of Major Trauma.” Journal of the American College of Surgeons 211, 804-811.

[2] MacKenzie, E., Rivara, F., Jurkovich, G., Nathens, A., Frey, K., Egleston, B., Salkever, D., Scharfstein, D., 2006. “A national evaluation of the effect of trauma-center care on mortality.” New England Journal of Medicine 354, 366-378.

[3] Schoell, S. L., Doud, A. N., Weaver, A.A., Talton, J.W., Barnard, R.T., Martin, R.S., Meredith, J.W. and Stitzel, J. D., 2014. “Development of a Time Sensitivity Score for Frequently Occurring Motor Vehicle Crash Injuries.” Journal of the American College of Surgeons.

[4] Brown, J.B., Stassen, N.A., Bankey, P.E., Sangosanya, A.T., Cheng, J.D., Gestring, M.L., 2011. “Mechanism of Injury and Special Consideration Criteria Still Matter: An Evaluation of the National Trauma Triage Protocol.” Journal of Trauma-Injury Infection and Critical Care 70, 268, 38-45.

[5] Widgren, B.R., Jourak, M., 2011. ”Medical Emergency Triage and Treatment System (METTS): A New Protocol in Primary Triage and Secondary Priority Decision in Emergency Medicine.” Journal of Emergency Medicine 40, 623-628.

[6] Buendia, R., Candefjord, S., Fagerlind, H., Bálint, A., Sjöqvist, B.A. 2015. “On Scene Injury Severity Prediction (OSISP) Algorithm for Car Occupants.” Submitted to Accident Analysis and Prevention.

[7] Buendia, R., Candefjord, S., Fagerlind, H., Bálint, A., Wege, C., Sjöqvist, B.A. 2015. “On Scene Injury Severity Prediction (OSISP) Algorithm for Truck Occupants.” Submitted to Traffic Injury Prevention.

[8] Howard, C. and Linder, A., 2014. “Review of Swedish experiences concerning analysis of people injured in traffic accidents.” Swedish National Road and Transport Research Institute (VTI) VTI Report, 7A-2014, 1-34.

[9] Harrell, F.E., 2001. “Regression modeling strategies, with applications to linear models, survival analysis and logistic regression.” Springer Science and Business Media, Inc., New York.

[10] Kononen, D.W., Flannagan, C.A.C., Wang, S.C., 2011. “Identification and validation of a logistic regression model for predicting serious injuries associated with motor vehicle crashes.” Accident Analysis & Prevention 43, 112-122.